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SUPPORT & SALES hereby certify that annexed is a true copy of the
Provisional specification in connection with Application No. PQ 4352 for a
patent by BISHOP AUSTRANS PTY LIMITED filed on 01 December 1999.

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WITNESS my hand this
Seventh day of August 2000

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A STEERABLE VEHICLE

5 TECHNICAL FIELD

This invention relates to a vehicle with a steerable wheelset. Whilst the invention is primarily described with an embodiment particularly suited for use with Automated Guideway Transit (AGT) systems of the type which use small,
10 individual vehicles, capable of operating at high speeds, the present invention is also suitable for use with a variety of other rail or guideway systems.

BACKGROUND

There are a number of known vehicles adapted to travel on rail or guideway
15 systems which have steerable wheelsets.

Such vehicles may use rubber tyred wheels running on a concrete or steel guideway, or steel wheels running on steel rails. The wheels are typically arranged in pairs in the form of wheelsets which are each pivotally mounted to
20 the vehicle body. Where the steering of the vehicle is controlled by an external device as in automated systems, it is common practice to mechanically limit the lateral travel of wheels, and hence the vehicle, with respect to the guideway. In guideway systems employing steel wheels running on steel rails, the wheels include flanges which engage the edge of the rail
25 heads, as in conventional railway technology. In other guideway systems employing rubber-tyred wheels running on steel or concrete guideways, extra rubber wheels mounted on a substantially vertical axis at each side of the wheelset engage a substantially vertical steel or concrete wall at each side of the guideway.

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However, guideway systems have been proposed in which there is no mechanical limit on the lateral travel of the wheels, and hence the vehicle, with respect to the guideway. One such system is disclosed in US Patent

4,982,671 (Chollet et al), and relates to a track guided vehicle. Such a vehicle is supported on bogies, where each bogie contains two wheelsets. Magnetic (or other) sensors are used to detect the lateral position of the bogie with respect to the track on which it is running. At least one sensor detects the angle between the two wheelsets. The two wheelsets are connected via linkages and actuators, such that the angle between the wheelsets can be altered to steer the bogie. A servo-control circuit receives signals from the sensors and controls the actuators to steer the wheelsets in response to the detected lateral position of the bogie.

Another known system is disclosed in European Patent 374,290 (Girod et al), and relates to a track guided vehicle. Such a vehicle comprises four wheels that can be independently steered. Laser sensors, located at the front and rear of the vehicle, are used to detect the difference between the track centreline and the vehicle longitudinal axis. A servo-control mechanism controls the steering actuators in order to steer the wheels in response to the sensed signals.

In any steering system, the lateral forces coming from the wheel-rail/wheel-guideway contact zone must serve both active and passive functions, namely, to steer the vehicle and also to oppose any lateral force, such as the centrifugal force experienced by a vehicle while cornering. Consequently the lateral frictional force available for steering the bogie is limited to the difference between the total available force and that already being used to oppose any external lateral forces. In a rail application where a steel wheel rolls on a steel rail, the total available lateral frictional force is very low as compared to vehicles using rubber tyres. This available force may be almost all required to react centrifugal force, and hence an insufficient amount of force remains to steer the vehicle and hence avoid flange contact.

Furthermore, In such systems, the wheel flanges permit only small deviations of the wheelsets from the desired path, and hence large momentary lateral forces may be demanded of the wheel-rail interface.

A further known system is disclosed in US Patent 5,730,064 (Bishop), and relates to a self-steering bogie for track guided vehicle employing, on each bogie, a leading and a trailing wheelset. The wheelsets are arranged such that a curvature in the rail generates a twist angle between the two wheelsets in the bogie when viewed in end elevation. The mechanism connecting the two wheelsets is arranged so as to steer the wheelsets, in response to rail curvature. A disadvantage of this arrangement is the tendency for lateral forces acting on the trailing wheelsets to provide a turning moment about the steering axis. This moment may add to or subtract from the ideal steering angle required, causing the wheelset to deviate from its idealised path.

Preferably the present invention overcomes the above mentioned disadvantages by providing a vehicle with a steerable wheelset in which the effect of lateral or disturbing forces on the vehicle is minimised.

SUMMARY OF INVENTION

In one aspect the present invention is a vehicle with at least one steerable wheelset adapted to run on a guideway having two primary running faces laterally offset about a guideway centreline, the wheelset comprising a pair of wheels, each wheel located on opposite sides of the wheelset adapted to engage with a respective one of the two primary running faces, the vehicle further comprising sensing means for sensing lateral displacement of the wheelset with respect to a longitudinally disposed reference path, the sensing means producing a signal for a control system operably connected to an actuating means to steer the wheels in response to the sensed lateral displacement, **characterised in that** both the axes of rotation of the wheels and the primary running faces are inclined downwardly towards the guideway centreline.

Preferably each wheel exerts an engagement force with its respective primary running face, the engagement force on each wheel comprising a first component perpendicular to its respective primary running face and a second

component parallel to its respective primary running face and substantially at right angles to the guideway centreline, wherein transverse horizontal forces acting on the wheelset are substantially resisted by the difference between the two horizontal vectors of the first components.

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Preferably each wheel exerts an engagement force with its respective primary running face at a contact zone, the engagement force on each wheel comprising a first component perpendicular to its respective primary running face and a second component parallel to its respective primary running face and substantially at right angles to the guideway centreline, wherein a first plane which is perpendicular to the axis of rotation of one of the wheels and which passes through the centroid of its respective contact zone, and a second plane perpendicular to the axis of rotation of the other wheel and which passes through the centroid of its respective contact zone, the first and second planes intersecting along an intersection line disposed above and between the wheels, further wherein horizontal lateral forces acting on the vehicle at or near the intersection line are substantially resisted by difference between the two horizontal vectors of the first components of the engagement forces acting at the primary running faces, such that the second components of the engagement forces acting at the primary running faces are adequate to supply steering forces.

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It is preferred that the intersection line passes through the centre of gravity of vehicle.

It is preferred that secondary running faces are provided on the guideway longitudinally adjacent to each primary running face.

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It is preferred that each wheel incorporates a flange, adapted to engage the secondary running face adjacent to the respective running face upon which it travels.

It is preferred that the longitudinally disposed reference path is contiguous with the secondary running face. Alternatively, it is preferred that the

secondary running face lies longitudinally adjacent to each primary running face and the longitudinally disposed reference path is contiguous with the lateral centreline between the respective two secondary running faces.

5 It is preferred that the sensing means comprises at least one sensor located either ahead or behind the wheelset, or laterally offset with respect to the wheelset. Alternatively, the sensing means comprises at least two sensors, one of which is located ahead of the wheelset and the other is located behind the wheelset.

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It is preferred that the longitudinally disposed reference path is substantially contiguous with the guideway centreline.

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Alternatively, it is preferred that the longitudinally disposed reference path is substantially parallel to, but laterally offset from the guideway centreline.

It is preferred that the control system calculates a virtual longitudinally disposed reference path which is not necessarily parallel or contiguous with the guideway centreline.

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It is preferred that the primary and secondary running faces respectively are the top and inside or outside faces of a rail.

25 **BRIEF DESCRIPTION OF DRAWINGS**

Figure 1 is an example of a vehicle according to the prior art, with two steerable wheelsets and incorporating steering sensors, actuators and a controller;

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Figure 2 is a wheelset as found in the vehicle in Figure 1, showing the forces acting at the wheel-to-guideway running faces;

Figure 3 is a graph representing a typical relationship between side-force and slip angle for a wheel of the wheelset in Figure 2, and showing the force available for steering the wheels;

- 5 Figure 4 shows a schematic representation of a vehicle in accordance with a first embodiment of the present invention;

Figure 5 shows a schematic representation of a vehicle as shown in figure 4 when the vehicle is in a turn;

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Figure 6 is a wheelset of the vehicle as shown in Figures 4-5, showing the forces acting at the wheel-to-guideway running faces;

- 15 Figure 7 is a graph similar to Figure 3, showing the force substantially available to steer the wheels in accordance with the first embodiment of the present invention;

Figure 8 is a wheelset and rails as described in a second embodiment of the present invention;

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Figure 9 shows a wheelset which is following a longitudinally disposed reference path other than the guideway centreline or secondary running face, according to a third embodiment of the present invention.

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MODE OF CARRYING OUT THE INVENTION

- 30 Figures 1 and 2 show a vehicle running on a guideway (or track) of the type described in prior art. Such a vehicle incorporates two steerable wheelsets 1, attached to a vehicle body 2, and each wheelset 1 comprising axle 10 and two wheels 12. Steering actuators 3, are used to control the angle of the wheels with respect to the body. Sensors 4, detect the path error between the vehicle and guideway 5. A controller 6, processes the signals from the sensors and

provides a control output to steering actuators 3. Upon detecting a path error, wheelsets 1 are steered in order to minimise the error.

In such a vehicle, axles 10 are substantially horizontal, as shown in Figure 2.

5 When a lateral force F is applied to the vehicle body 2, it is reacted by the wheel-to-guideway engagement forces. These reaction forces can be resolved into perpendicular components, A_N and B_N , and parallel components, A_T , B_T . When a wheel is steered at an angle to its heading, generating a slip angle, small levels of slip at its contact zone generate a lateral force (A_T , B_T).

10 This lateral force is related to this slip angle, with a typical relationship of the form shown in the graph of Figure 3. Such a relationship depends on both the wheel and guideway materials, along with their surface texture and any contamination thereof. The available side force reaches a maximum at a slip angle δ_1 , beyond which no additional side force is available. In the example
15 shown in Figure 2, wheelset 1 is steered so that lateral force F is reacted by a combination of A_T and B_T where A_T is equal to C_1 as shown graphically in Figure 3. To generate a force C_1 wheelset 1 must be steered so that wheel 12 generates a slip angle δ_0 to its heading. Only the remaining force C_2 is available to steer wheelset 1. If the required side force exceeds C_2 , steering
20 control is lost, the wheel slides in the direction of force F and is unable to follow a desired path. In such an event, the wheelset must rely on other means, such as wheel flanges or other mechanical travel limits, to ensure it remains safely on the guideway.

25 Figures 4 to 6 show a first embodiment of a vehicle according to the present invention comprising steerable wheelsets 21, each comprising axle 26 and two wheels 15 running on primary running faces 54 of guideway 19, attached to vehicle body 16. Steering actuators 17, are used to control the angle of wheelsets 21 with respect to vehicle body 16. Sensors 18, detect the lateral
30 displacement between the vehicle and guideway 19. Controller 20 processes the signals from sensors 18, and provides an output to the steering actuators as a function of the lateral displacement of wheelset 21 with respect to

guideway centreline 39. Upon detecting a lateral displacement error, wheelsets 21 are steered in order to minimise the error.

As shown in Figure 6, axes of rotation 28 of wheels 15 (mounted to stub axles 25) are inclined downwardly towards guideway centreline 39, as are primary running faces 54 at the wheel-to-guideway rolling interface. When a lateral force F is similarly applied to vehicle body 16, it is reacted by the wheel-to-guideway engagement forces. These can be resolved into first components P_N and Q_N perpendicular to primary running faces 54, and second components P_T and Q_T parallel to primary running faces 54. Each of these have a component parallel to the applied lateral force F , and in combination react against this force.

On entering a turn, sensors 18 detect the deviation of the vehicle from guideway centreline 39, and controller 20 responds by steering wheelset 21 in the direction to reduce the deviation to zero. The resulting slip angle δ produces lateral forces at the wheel-to-guideway interface, directed towards the centre of curvature of the guideway. The centrifugal force F , acting on the centre of gravity 50 of the vehicle, is substantially reacted by an increase in the perpendicular component P_N , on the outer wheel, rather than an increase of the parallel components, P_T and Q_T . If P_T and Q_T are small, then the wheels can operate at a small slip angle δ_0 as shown in Figure 7. As a result, most of the maximum available tangential force C_2 can be used to steer wheelset 21, and maintain its alignment with guideway centreline 39.

It is preferred that vehicle centre of gravity 50 and wheels 15 are arranged such that centre of gravity 50 is near the intersection line 52 of wheel planes 51. In this configuration, the centrifugal forces or external disturbance forces acting on centre of gravity 50, are substantially resisted by an increase in the perpendicular component P_N on the outer wheel, and corresponding decrease in the perpendicular component Q_N on the inner wheel. The higher the centre of gravity relative to the intersection line 52, the greater the difference between P_T and Q_T and P_N and Q_N . It will be seen that the efficiency of the

system is reliant on the degree of weight transfer under the influence of any or all disturbing forces. When there is no such forces, P_T and Q_T are equal (and small) and P_N and Q_N are also equal. Such weight transfer is affected by superelevating the guideway or by active roll.

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Figure 8 depicts a second embodiment of the present invention, where the vehicle has a wheelset 21 comprising wheels 15 adapted to run on a guideway in the form of rails 19. The primary running face 54 is the top face of each rail, whilst the secondary running face 38 is the inside face of each rail

10 19. Sensors 18 detect the distances d_1 , d_2 of the wheels 15 to the respective secondary running face 38 on rails 19. Sensed distances d_1 , d_2 are subtracted and halved ie. $(d_1 - d_2)/2$, to calculate the lateral position of the centreline 49 of the wheelset 21, with respect to the guideway centreline 39. In this embodiment each of the wheels 15 have a respective flange 37.

15 Flange 37 engages with respective secondary running face 38 on rail 19 in the event of a steering failure, or excessive side load imparted on the vehicle via lateral acceleration or side wind loads. In other not shown embodiments, sensors 18 may detect the distance of the wheels to some other feature on rail 19. Also secondary running face 38 may alternatively be located on the outside face of

20 each rail 19.

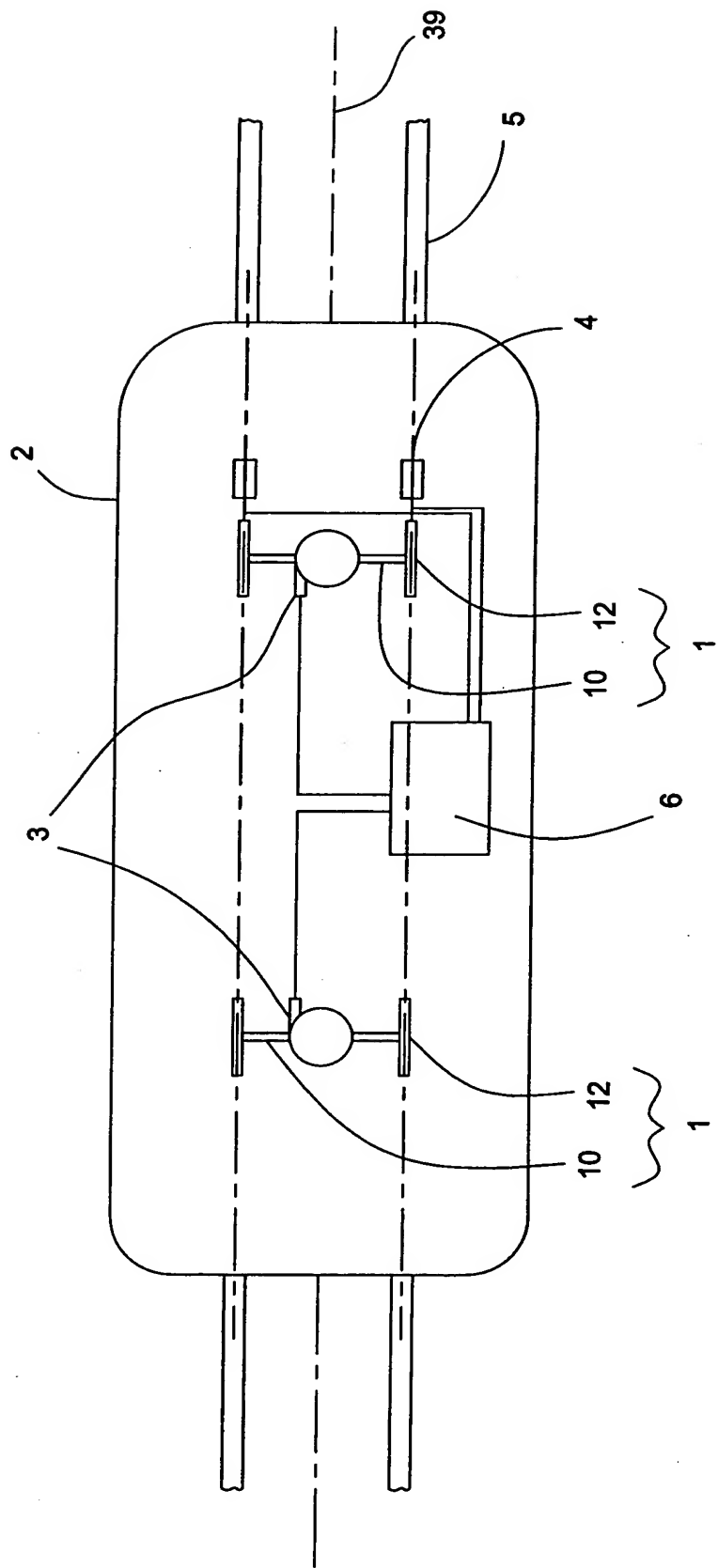
In a third embodiment of the invention as shown in Figure 9, sensor 18 is shown as detecting longitudinally disposed reference path 41, positioned at guideway centreline 39. However, it should be understood that such a path

25 may physically lie anywhere between primary running faces 40, as depicted by phantom lines as reference path 41a and sensor 18a, or outside primary running faces 40, as depicted by phantom lines as reference path 41b and sensor 18b. Alternatively the longitudinally disposed reference path may be a virtual path, bearing some predetermined varying relationship to the primary

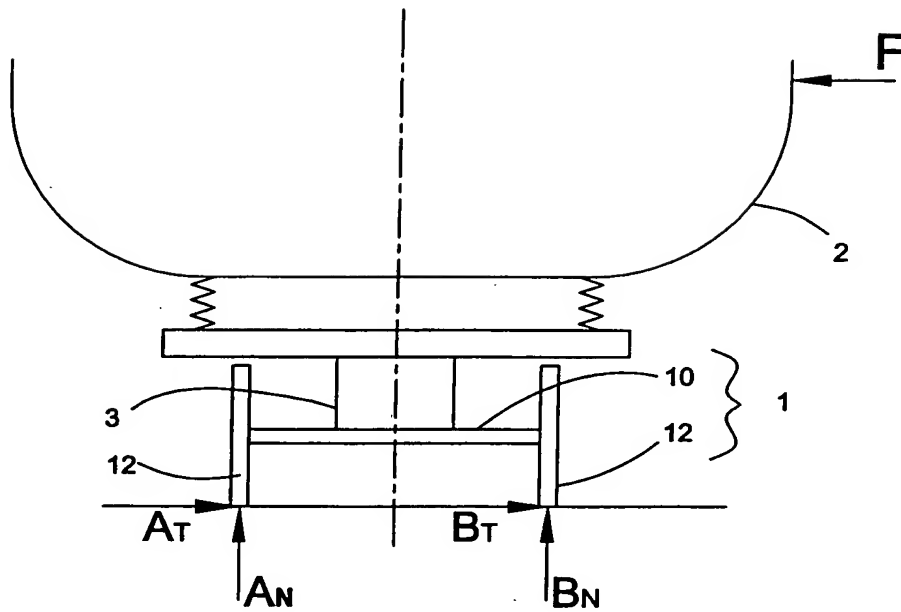
30 running faces 40. Sensors 18 are preferably located ahead of wheelset 21 and are connected to controller 20. In other not shown embodiments, sensors 18 may be located ahead, beside, and/or even behind the wheelset 21.

In another not shown embodiment, the steering actuator system may comprise a hydraulic system. For example, sensors 18 may be replaced by hydraulic valves and actuators 17 by hydraulic cylinders fluidly connected to a pressurised source of fluid. Alternatively, sensors 18 may be replaced by
5 mechanical contact devices, linked mechanically to a centrally located hydraulic control valve, which perform the subtraction function described in the above mentioned embodiment.

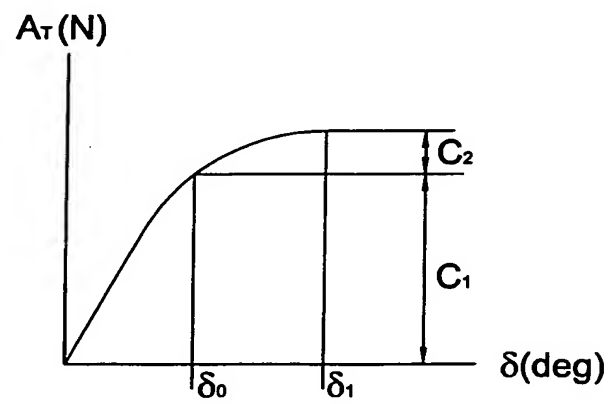
It will be recognised by persons skilled in the art that numerous variations and
10 modifications may be made to the invention without departing from the spirit and scope of the invention.



PRIOR ART
Figure 1



PRIOR ART
Figure 2



PRIOR ART
Figure 3

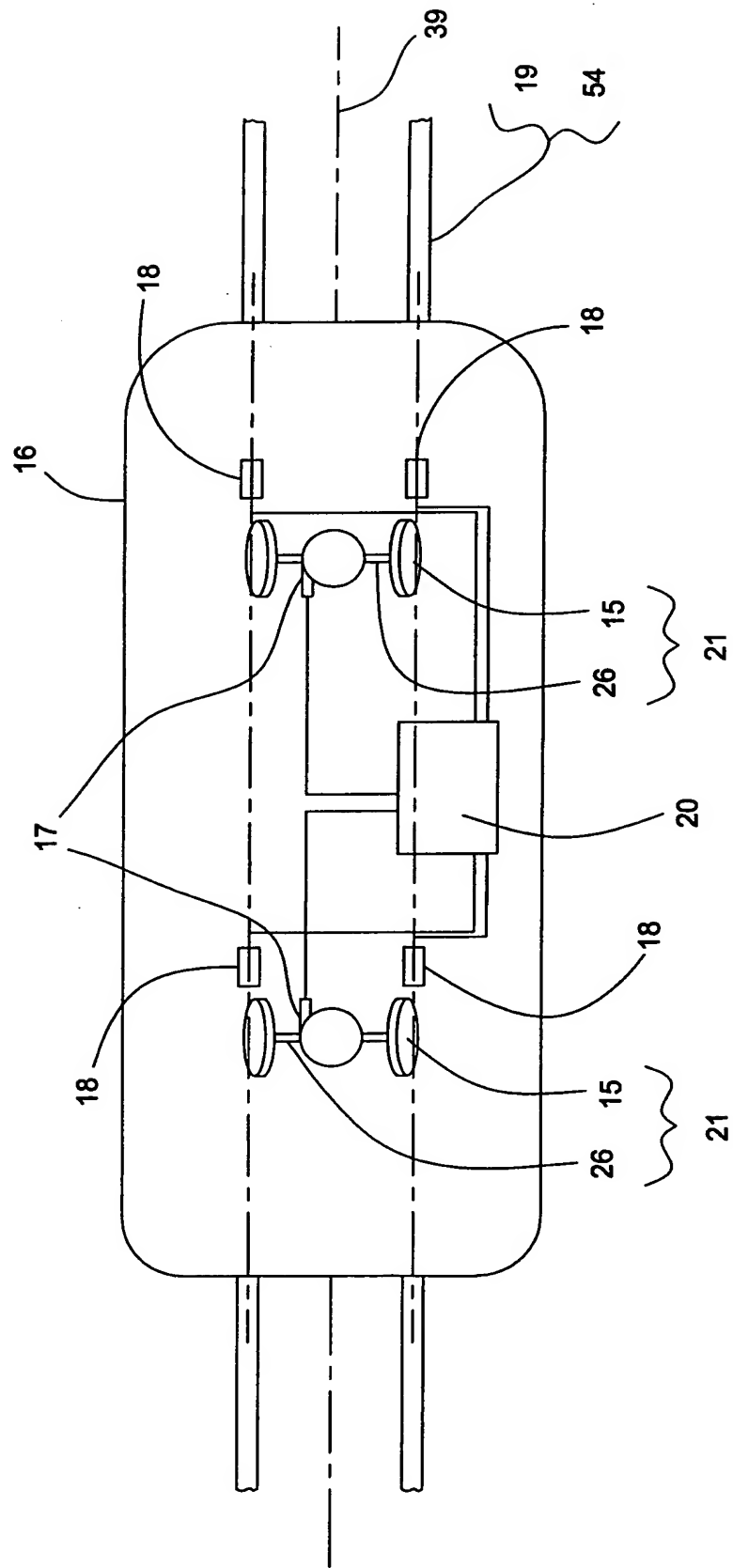


Figure 4

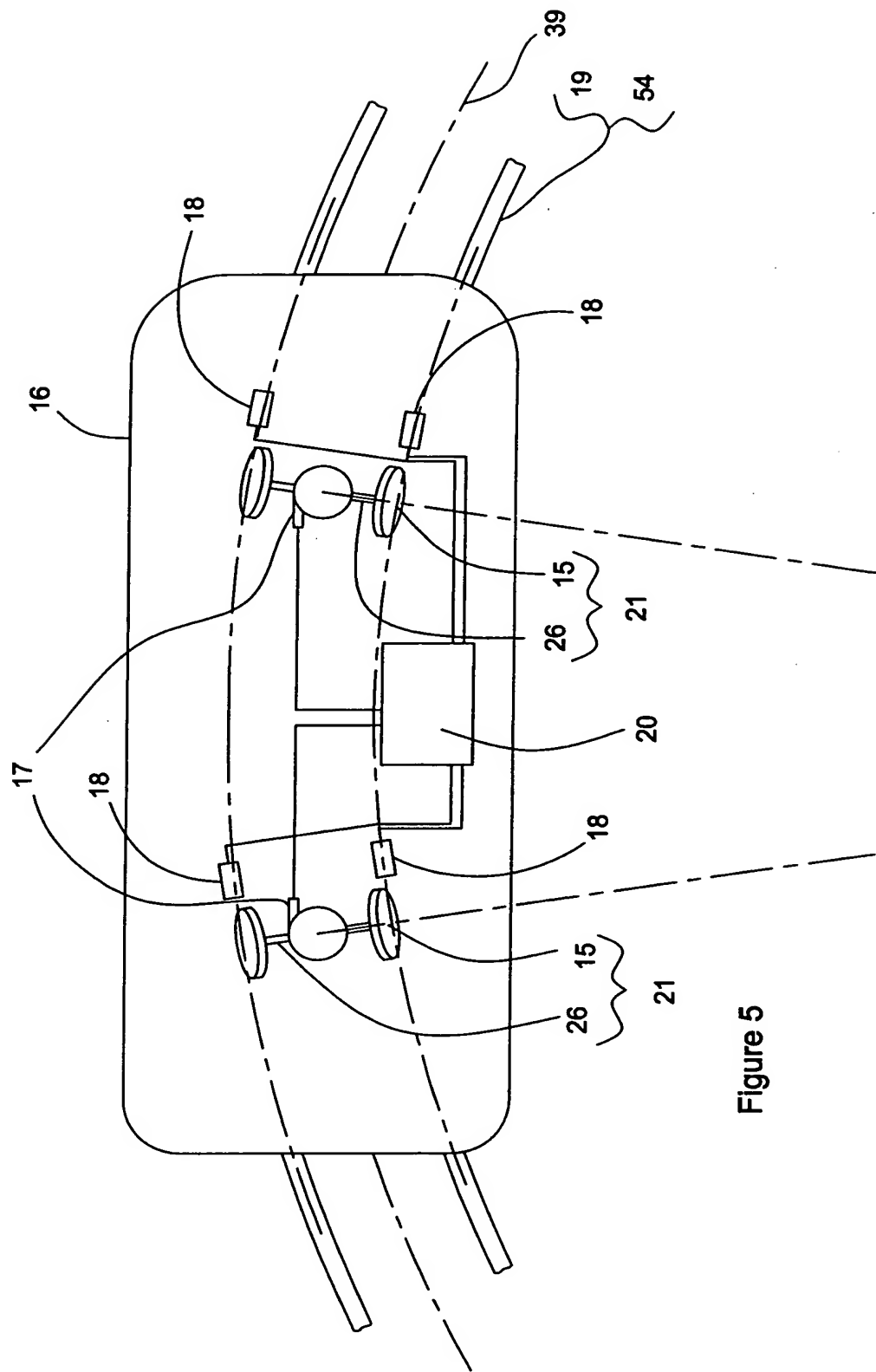


Figure 5

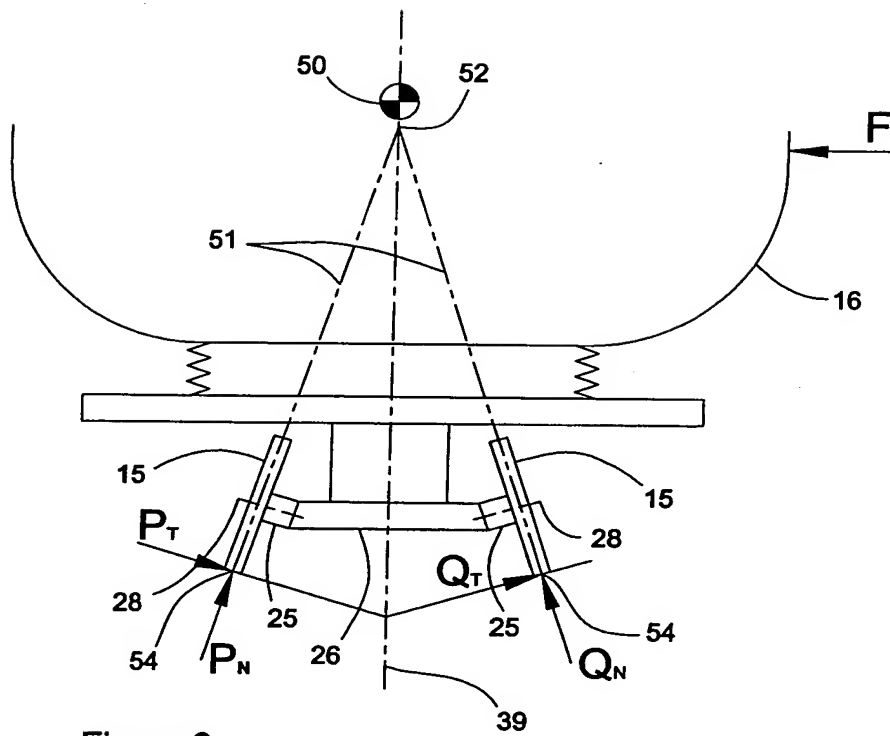


Figure 6

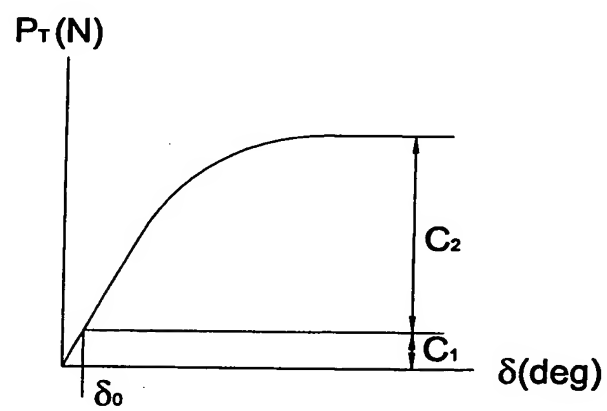


Figure 7

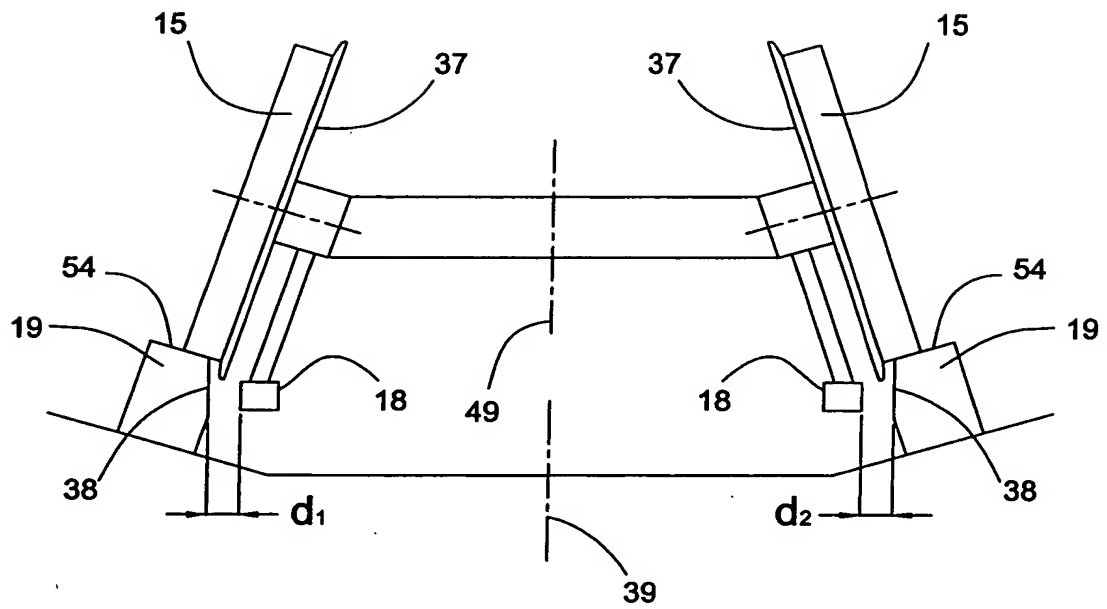


Figure 8

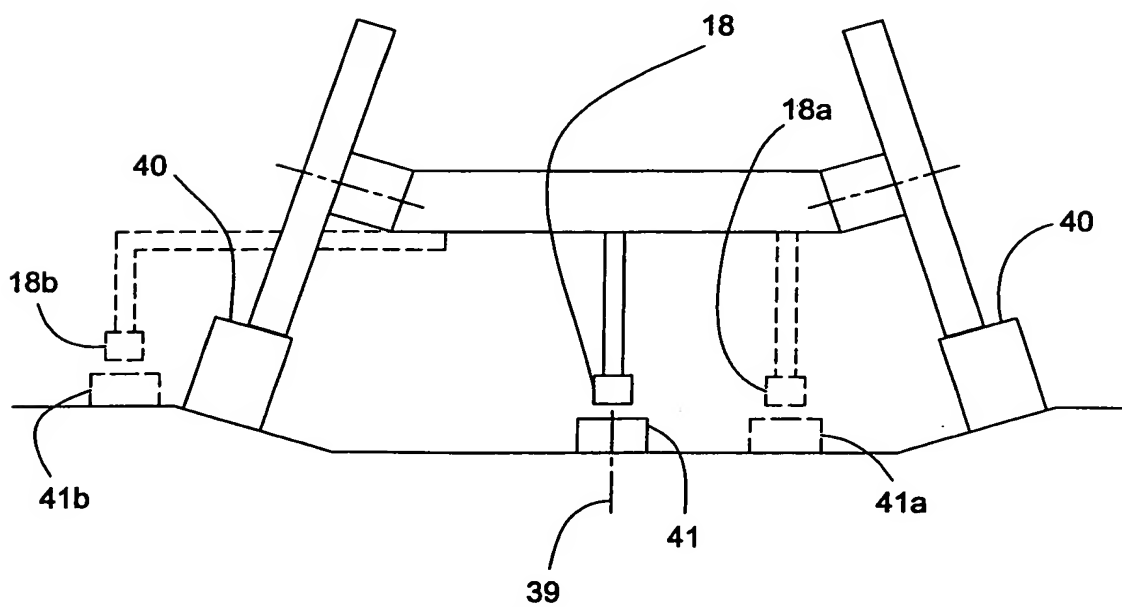


Figure 9

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